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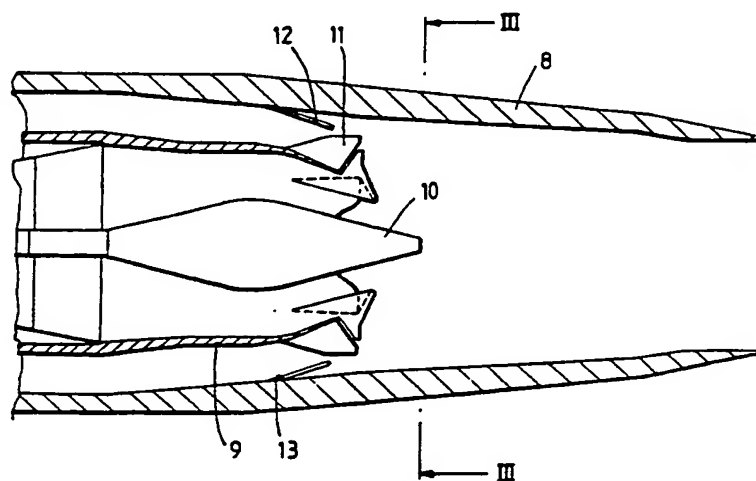
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(54) Vortex silencing in gas turbine engines

(57) A gas turbine engine has means to reduce audio frequency noise emission by reducing vorticity in the exhaust gases. Vortex generators 12 situated in the bypass duct of the gas turbine engine induce vortices in the relatively cool bypass air, the generators being configured such that the cool vortices are superimposed upon those generated by the lobes of a mixer nozzle 11. The vortex generators may comprise triangular parts (Figs 2 to 5) protruding into the bypass flow. Alternatively they may comprise air injectors (Fig 6) comprising a discharge orifice (14) in the cowl wall (8) linked to a supply of high pressure air bled from the engine compressor.

Fig.2.



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Fig.1.

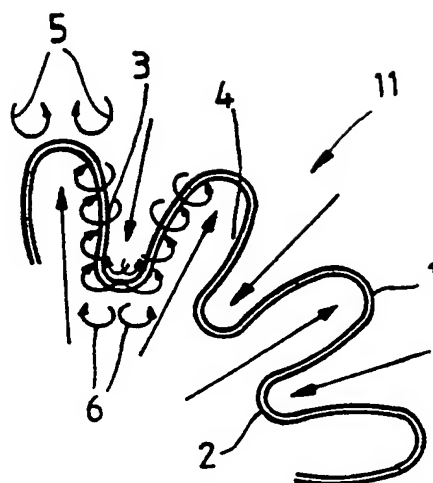
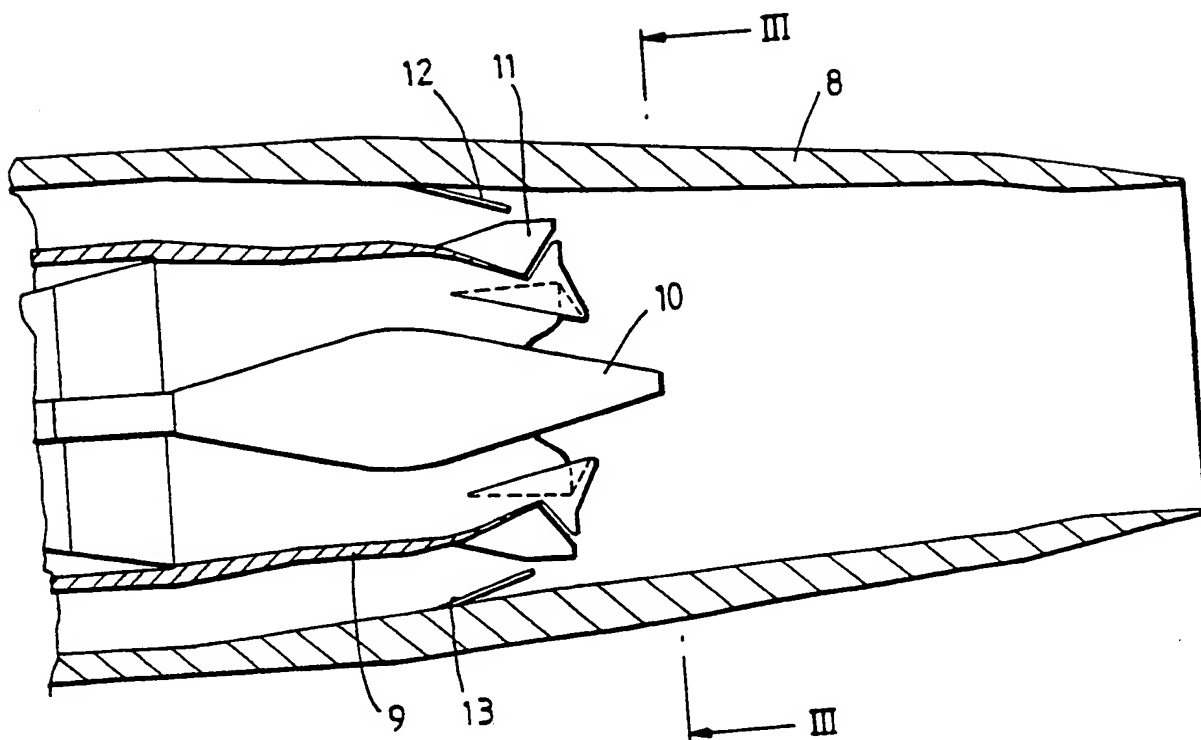
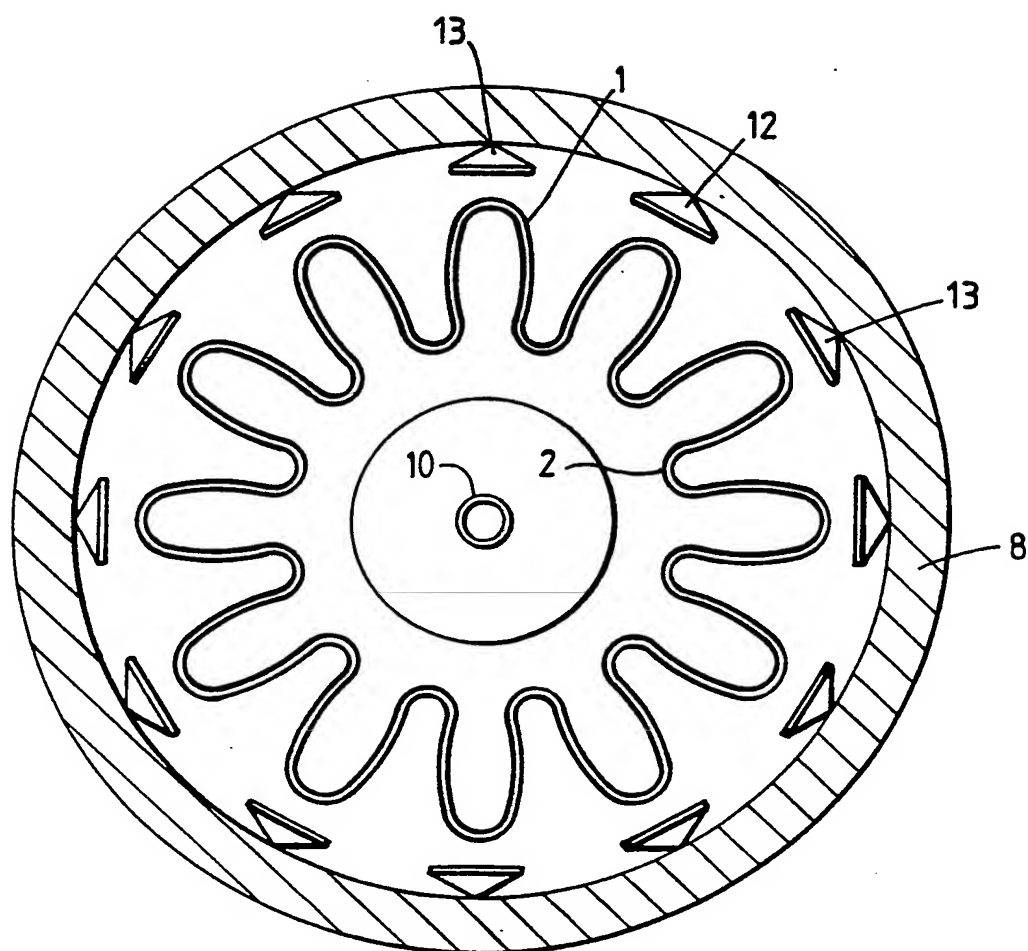


Fig.2.



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Fig. 3.



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Fig. 4.

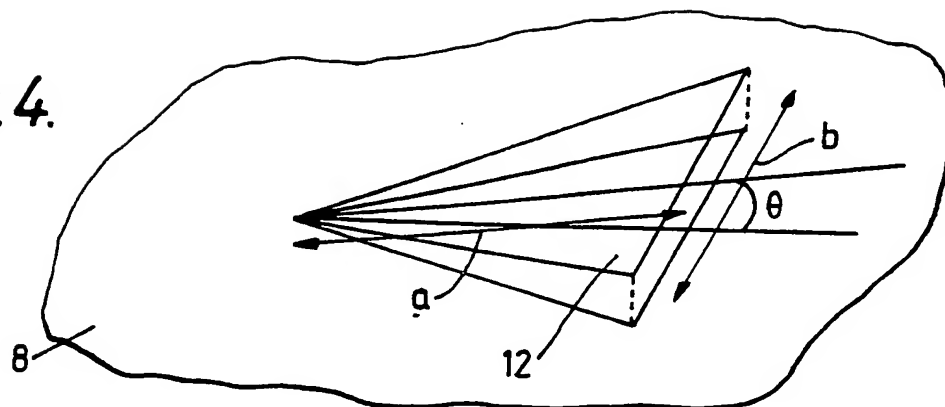


Fig. 5.

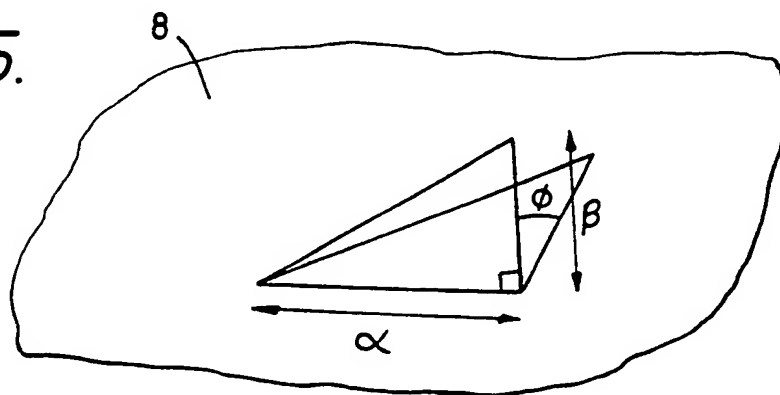
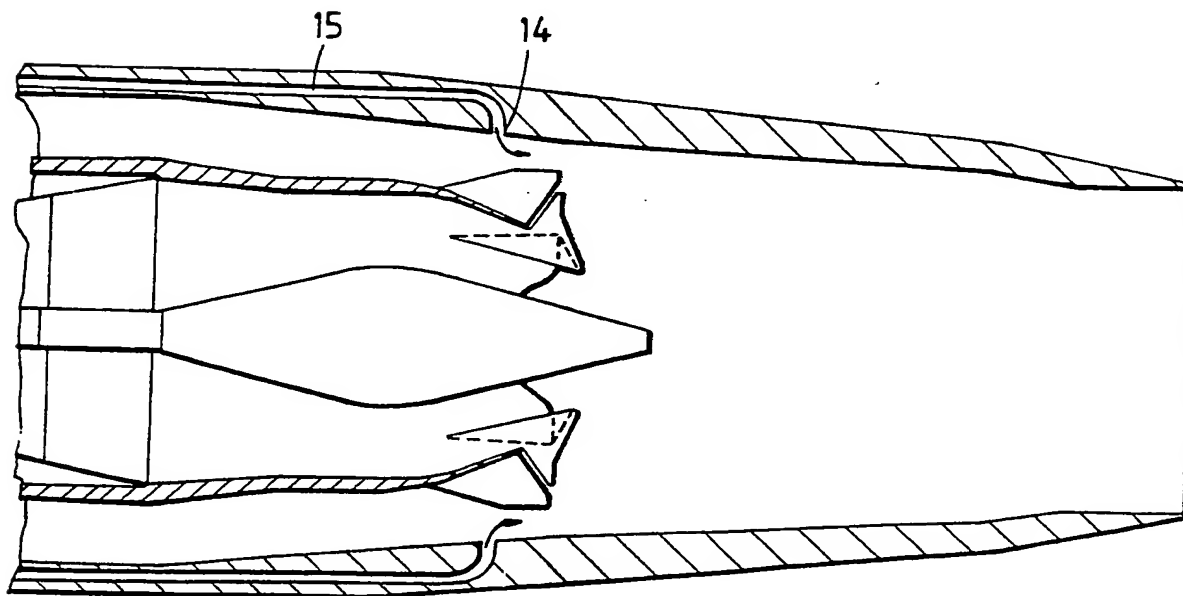
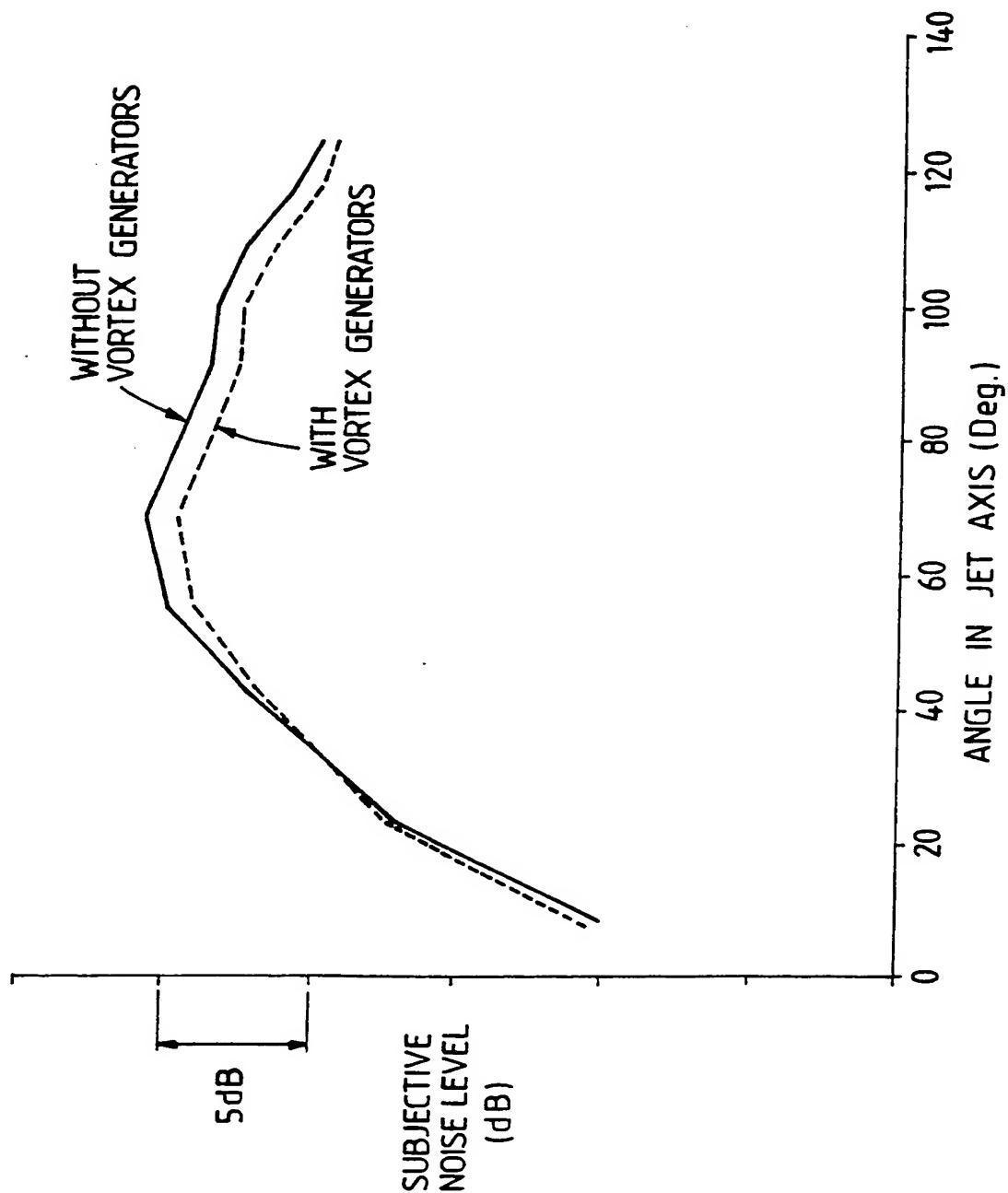


Fig. 6.



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Fig.7.



NOISE SUPPRESSION IN GAS TURBINE ENGINES

The present invention relates to the suppression of audio-frequency noise in bypass flow gas turbine engines.

With more powerful aircraft engines and increased numbers of aircraft operations noise is of great concern, especially
5 with regard to night flying into urban airports. Pressure to reduce noise levels and ever more rigorous statutory limits mean new methods to improve noise suppression are desirable.

One source of noise in all jet engines is the shearing force at the interface between high speed exhaust air and the
10 relatively undisturbed ambient air of the atmosphere. In present bypass engines, the exhaust airflow takes the form of a hot core flow surrounded by a relatively cold bypass flow. In some current engine designs the core flow exhausts from a nozzle which is inside a larger and longer nozzle which
15 encloses the bypass flow. The noise of such configurations can be suppressed by some sort of mixer nozzle on the downstream end of the cowl enclosing the core flow. One known form of mixer has a lobed construction where the lobes are contoured to form a 'scarfed' geometry.

20 This type of mixer interleaves jets of outward flowing core air with inward flowing bypass air to combine the two and is employed in most engines produced by the major manufacturers. The outer wall of the annular bypass duct extends downstream beyond the end of the lobed mixer to create
25 a region where mixing of bypass and core flows can occur before

these pass out through the final exhaust nozzle to the surrounding atmosphere. Weight constraints however prevent the outer wall being extended far enough for mixing to be complete although the exhaust noise, particularly at low audio
5 frequencies, can be reduced.

It is known that interaction between the hot core and cold bypass flows at the mixer lobes creates streamwise vortices. The sites of vortex generation in a conventional bypass flow gas turbine engine having a lobed mixer are illustrated in
10 Figure 1 of the drawings which is a partial transverse view of such an engine in the mixer zone. The mixer has outer lobes 1 and inner lobes 2. Hot core air flows away from the centre in the outer lobes 1 and cool bypass air flows towards the centre through the inner lobes 2. Vortices 3 rotating in the same
15 sense, clockwise or anti-clockwise hereinafter referred to as co-rotational, are formed along each side lobe 4. Corner vortices 5 are found opposite the outer lobes 1 and corner vortices 6 are found opposite the inner lobes 2. The series of co-rotational vortices at each lobe fuse to form a single
20 vortex of opposite rotational sense to those formed at adjacent lobe sides.

For other lobe type mixers the vortex sources may not be positioned as in Figure 1 and more than one vortex pair may originate from each lobe. The interaction between the core and
25 bypass flows at the lobes however will still be responsible for the configuration of vorticity in the exhaust.

The present invention is a bypass gas turbine engine having a lobed mixer and incorporating means for reducing audio-frequency noise by reduction of vorticity therein, this
30 means comprising vortex generator means situated in the bypass flow duct, positioned to induce vorticity in the bypass flow in configuration to superimpose upon some of the vortices occurring naturally at the mixer a vortex originating in the bypass flow of like sense, size and intensity. The vortices
35 engineered in the cool bypass flow will hereinafter be referred to as cold vortices.

One preferred vortex generator means comprises a delta wing device with apex and trailing edge having its apex on or near the outer wall of the bypass flow duct and set at an angle to the bypass flow stream. Such a vortex generation means
5 would produce a pair of vortices of opposite rotation known as a vortex pair. This construction is convenient as its implementation is relatively straightforward.

Another preferred vortex generator means comprises a half delta wing device having an apex and trailing edge mounted by
10 its root edge and located on or near the outer wall of the bypass duct arranged at an angle to the bypass flow. The half delta wing device creates a single vortex having a rotational sense fixed by the orientation of the wing. This form of generator would allow precisely directed vortices of either
15 rotation to be created.

The wing form vortex generators may be retractable to allow them to be withdrawn from the bypass flow to minimise drag during periods when audio-frequency noise suppression is not required. A hinged construction is preferred.

20 An alternative means of vortex generation comprises an air injector situated in the bypass flow duct wall connected to a source of high pressure air, preferably bleed air from the compressor stage of the engine, the air injector directing a high pressure jet through a hole in the bypass duct wall in a
25 downstream direction having a cut-off means to allow air flow to be stopped when not required. A jet of air obstructs flow in the bypass duct in the same way as a wing protrusion with consequential engine losses due to drag. However with this embodiment the air jet could be shut off to remove the
30 obstruction. This could reduce drag to a level below that achievable with retractable wing vortex generators.

The invention is now described with reference to Figures 2-8 of the drawings of which:

Figure 2 is a longitudinal section through a bypass gas
35 turbine engine in the downstream region showing vortex generators of delta wing form.

Figure 3 is a transverse section through the bypass gas turbine engine of Figure 2 along line x-x.

Figure 4 is a perspective view of a delta wing vortex generator positioned on the outer wall of a bypass duct.

5 Figure 5 is a perspective view of a half delta wing vortex generator positioned on the outer wall of a bypass duct.

Figure 6 is a longitudinal section through a gas turbine engine having vortex generators of an injector type.

10 Figure 7 is a graph plotted of overall noise in decibels at a constant distance from the jet axis plotted against angle to the jet axis.

A bypass engine has a low pressure compressor fan directing air through the engine core into further compressor, combustion and turbine stages and also into a surrounding
15 bypass duct. Downstream of the exit from the turbine section the core flow is caused to mix with the bypass flow. Figure 2 shows a bypass gas turbine engine in the downstream mixer region and Figure 3 shows a cross section of the engine in Figure 2 along the line x-x. The engine has an outer cowl 8 and an inner cowl 9. Bypass air flows through the duct defined
20 by the outer and inner cowls 8 and 9. There is a turbine exit central body 10 which is aerodynamically shaped to reduce engine drag. Hot core gas flows through the region bounded by the inner cowl 9 and the central body 10. A lobed mixer nozzle
25 11 is attached to the downstream end of the inner cowl wall 9. Vortex generators 12 are located in the bypass duct. Each is attached to the cowl wall 8 by its apex 13. These generators 12 are best seen with reference to Figure 5. Vortex fusion between vortices generated in the bypass flow and those
30 occurring naturally at the lobed mixer takes place in the region bounded by the outer cowl 8 downstream of nozzle 11.

A specific vortex configuration is required in the bypass flow for superimposition upon vorticity created at the mixer lobes. In order to achieve this a precise circumferential
35 positioning of the vortex generator means is necessary. When

arranging the generator means the exact site of vortex generation and considerations such as swirl in the bypass flow must be taken into account. The longitudinal positioning of the vortex generators is relatively unimportant. It is however
5 easier to direct the vortices when produced close to rather than far from the region of fusion.

The exact construction of the vortex generator means employed is dictated by the particulars of the vortices generated at the lobed mixer. These will differ between
10 engines. The delta wing construction shown in Figure 5 produces a vortex pair that will differ in intensity and size depending upon the angle θ between the delta wing 12 and the outer cowl wall 8, the length a, and breadth b, of the delta wing. Intensity of the vortices will increase with θ and
15 vortex size will increase with the length b. The dimensions and angles are chosen so that cold vortices similar in magnitude and intensity to those created at the lobed mixer are produced.

One specific example of the invention is a 1/13th scale
20 model of a modern gas turbine engine exhaust system having a lobed mixer with twelve lobes as shown in Figure 3 and having delta wing vortex generator means as shown in Figure 4 inclined at an angle of 17° to the bypass flow stream measuring 0.5 in. from apex to trailing edge and 0.2 in. across the trailing
25 edge, attached to the outer cowl wall 8.

A third embodiment of the invention is shown in Figure 6. This incorporates vortex generators in the form of air injectors. The injectors each comprise a discharge orifice 14 in the outer cowl wall 8 which is linked to a supply of high
30 pressure air bled from the compressor stage by a supply duct 15. In use a jet of high pressure air issues from each orifice 14 to form a blockage in the bypass flow. This blockage results in the formation of a vortex pair with size and strength dependent upon the pressure and diameter of the jet
35 and the angle of incidence to the bypass flow. These

parameters are equivalent to the length, breadth and angle of incidence respectively of the delta wing and can similarly be set to produce the vorticity required. The jet pressure can be set by taking bleed air from an appropriate stage of the compressor and the vorticity created can be controlled by engineering the diameter of the hole and angle of incidence to the flow appropriately. To avoid unnecessary drag when vortex generation is not needed there is provided a means in the form of a valve (not shown) to cut off the supply flow present in the supply duct.

A certain amount of trial and error may be necessary before the right design and configuration of vortex generators for an individual engine is achieved. It can be seen however by looking at Figure 7 of the drawings that the overall noise level can be reduced by as much as 0.5 dB at some angles to the jet axis. This degree of improvement could well be of considerable significance when noise is close to the control regulation limit.

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CLAIMS

1. A bypass gas turbine engine having a lobed mixer and incorporating means for reducing audio frequency noise by reduction of vorticity therein, this means comprising vortex generator means situated in the bypass flow duct positioned to induce vorticity in the bypass flow in configuration to superimpose upon some of the vortices occurring naturally at the mixer a vortex originating in the bypass flow of like sense, size and intensity enabling fusion to occur prior to exit through the exhaust nozzle.
2. A gas turbine engine as claimed in claim 1 wherein each vortex generator means comprises a delta wing device with apex and trailing edge having its apex on or near the outer wall of the bypass flow duct arranged at an angle to the bypass flow stream.
3. A gas turbine engine as claimed in claim 1 wherein each vortex generator means comprises a half delta wing device with apex and trailing edge mounted by its root edge and located on or near the outer wall of the bypass duct arranged at an angle to the bypass flow.
4. A gas turbine as claimed in claim 2 or 3 wherein the vortex generator means are hinged to allow retraction from the flow in the bypass duct.
5. A gas turbine engine as claimed in claim 1 wherein each vortex generator means comprises an injector situated in the outer wall of the bypass duct connected to a source of high pressure air directing a high pressure jet through a hole in the bypass duct wall into the bypass flow in a downstream direction.
6. A gas turbine engine as claimed in claim 5 wherein the source of high pressure air is bleed air from the compressor stage of the engine.

7. A gas turbine engine as claimed in claims 5 or 6 wherein the injector has a cut off means to remove the jet when not required.

8. A gas turbine engine substantially as hereinbefore described with reference to Figures 2-7 of the drawings.